

What is claimed is:

1           1.     A method of depositing a metal layer on a wafer, the method comprising:  
2           immersing the wafer in an electrolytic solution containing metal ions; and  
3           biasing the wafer negatively with respect to the electrolytic solution so as to  
4           create a current flow between the electrolytic solution and the wafer and thereby  
5           electroplate a metal layer on a surface of the wafer by first biasing the wafer to produce  
6           a first current density, then secondly biasing the wafer to produce a second current  
7           density, the second current density being greater than zero and less than the first  
8           current density.

1           2.     The method as in claim 1, wherein the biasing the wafer further includes,  
2           after the secondly biasing, thirdly biasing the wafer to produce a third current density,  
3           the third current density being greater than the second current density.

1           3.     The method as in claim 1, wherein the biasing the wafer further includes,  
2           after the secondly biasing, thirdly biasing the wafer to produce a third current density,  
3           the third current density being greater than the first current density.

1           4.     The method as in claim 3, wherein the biasing the wafer negatively  
2           includes, after the thirdly biasing, further electroplating using a succession of steps of  
3           increasing current densities, the succession of steps beginning with a fourth step having  
4           a fourth current density being greater than the third current density.

1           5.     The method as in claim 4, wherein a film deposition rate produced by the  
2           second current density is less than 0.01 times as great as an average film deposition  
3           rate during the thirdly biasing and the succession of steps.

1           6.     The method as in claim 3, wherein the first biasing, the secondly biasing,  
2           and the thirdly biasing are carried out in-situ.

1           7.     The method as in claim 3, wherein the first current density lies within a  
2           range of 0.003 to 0.08 amps/cm<sup>2</sup> and the third current density lies within a range of  
3           about 0.003 to 0.08 amps/cm<sup>2</sup>.

1           8.     The method as in claim 1, wherein the second current density is no  
2 greater than 0.0016 amps/cm<sup>2</sup>.

1           9.     The method as in claim 8, wherein the secondly biasing takes place for a  
2 time of 1 to 30 seconds.

1           10.    The method as in claim 1, wherein the second current density produces a  
2 film deposition rate no greater than 45 Å/minute.

1           11.    The method as in claim 1, wherein the first biasing takes place for a first  
2 time of 1 to 15 seconds and the secondly biasing takes place for a second time of 1 to  
3 30 seconds.

1           12.    The method as in claim 1, wherein the metal ions are copper ions and the  
2 metal layer comprises copper.

1           13.    The method as in claim 1, wherein the surface includes an upper portion  
2 and an opening extending downwardly therefrom and the biasing the wafer negatively  
3 produces the metal layer substantially completely filling the opening.

1           14.    The method as in claim 13, wherein the opening is a via that includes a  
2 width no greater than 0.25 microns.

1           15.    The method as in claim 1, wherein the electrolytic solution is in a bath and  
2 includes a flow rate of 5-20 liters per minutes.

1           16.    The method as in claim 1, wherein the electrolytic solution includes an  
2 accelerator having a concentration of about 1-16 milliliters/liter and a suppressor having  
3 a concentration of about 1-10 milliliters/liter.

1           17.    The method as in claim 1, further comprising depositing a seed layer on  
2 the surface prior to the biasing.

1           18.    A method of electrochemically depositing a metal layer on a wafer, the  
2 method comprising:

3            depositing a seed layer on a surface of the wafer;  
4            electroplating the metal layer on the wafer by:  
5            first immersing the wafer in a first electrolytic solution containing metal ions and  
6 first biasing the wafer negatively with respect to the first electrolytic solution so as to  
7 create a first current flow and a first current density;  
8            then immersing the wafer in a second electrolytic solution that contains metal  
9 ions and secondly biasing the wafer negatively with respect to the second electrolytic  
10 solution so as to create a second current flow and a second current density, the second  
11 current density being greater than zero and less than the first current density; and  
12            then immersing the wafer in a third electrolytic solution that contains metal ions  
13 and thirdly biasing the wafer negatively with respect to the third electrolytic solution so  
14 as to create a third current flow and a third current density, the third current density  
15 being greater than the second current density.

1            19. The method as in claim 18, wherein immersing the wafer in a second  
2 electrolytic solution takes place for a time of 1 to 30 seconds and includes the second  
3 current density being no greater than 0.0016 amps/cm<sup>2</sup>.

1            20. The method as in claim 18, wherein the third current density is greater  
2 than the first current density.

1            21. A process recipe for electroplating a metal film onto a substrate by  
2 electrochemical deposition, comprising a first step with a first bias to create a first  
3 current density between the substrate and an electrolytic solution, a second step  
4 following the first step and having a second bias to create a second current density  
5 between the substrate and the electrolytic solution, the second current density being  
6 greater than zero and less than the first current density, and subsequent steps of  
7 continuously increasing current densities beginning with a third step that follows the  
8 second step and has a third bias that creates a third current density between the  
9 substrate and the electrolytic solution, the third current density being greater than the  
10 first current density.

1           22.    The process recipe as in claim 21, wherein the second current density is  
2   no greater than  $0.0016 \text{ amps/cm}^2$  and produces a deposition rate less than about 50  
3   Å/minute.

1           23.    The process recipe as in claim 21, wherein the second step includes a  
2   time of 1 to 30 seconds, the first current density lies within a range of 0.003 to 0.08  
3   amps/cm<sup>2</sup> and the third current density lies within a range of about 0.003 to 0.08  
4   amps/cm<sup>2</sup>.